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Higaki

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(54) **CHARGING DEVICE, IMAGE FORMING UNIT AND IMAGE FORMING APPARATUS**

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G03G 15/16 (2006.01)

(52) **U.S. Cl.**
CPC ***G03G 15/0233*** (2013.01); *G03G 15/025* (2013.01); *G03G 15/0208* (2013.01); *G03G 15/0216* (2013.01); *G03G 15/1685* (2013.01); *G03G 2215/021* (2013.01); *G03G 2221/183* (2013.01)

(58) **Field of Classification Search**
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USPC 399/176
See application file for complete search history.

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(57) **ABSTRACT**

A charging device includes a charging member that charges a surface of an image bearing body. The charging member includes a rotation shaft applied with a voltage, and a resilient conductive layer provided on an outer circumferential surface of the rotation shaft. The resilient conductive layer charges the surface of the image bearing body. The resilient conductive layer has a plurality of high resistance regions arranged at intervals in an axial direction of the rotation shaft.

15 Claims, 5 Drawing Sheets

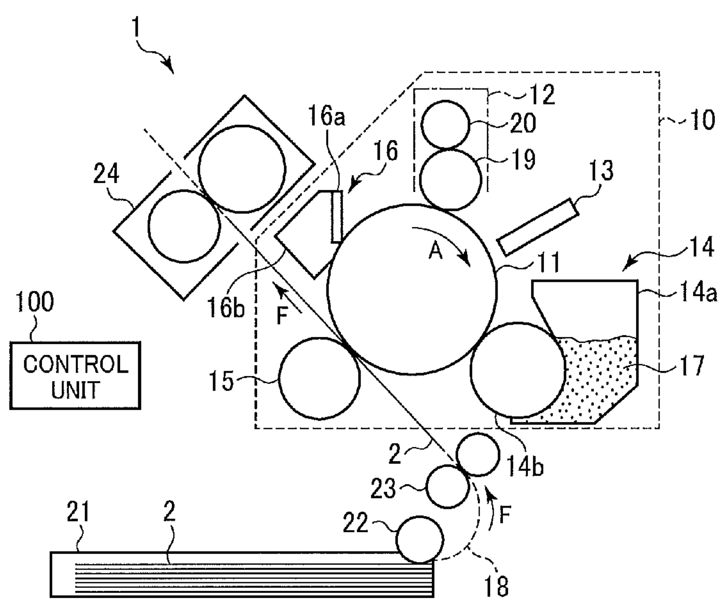
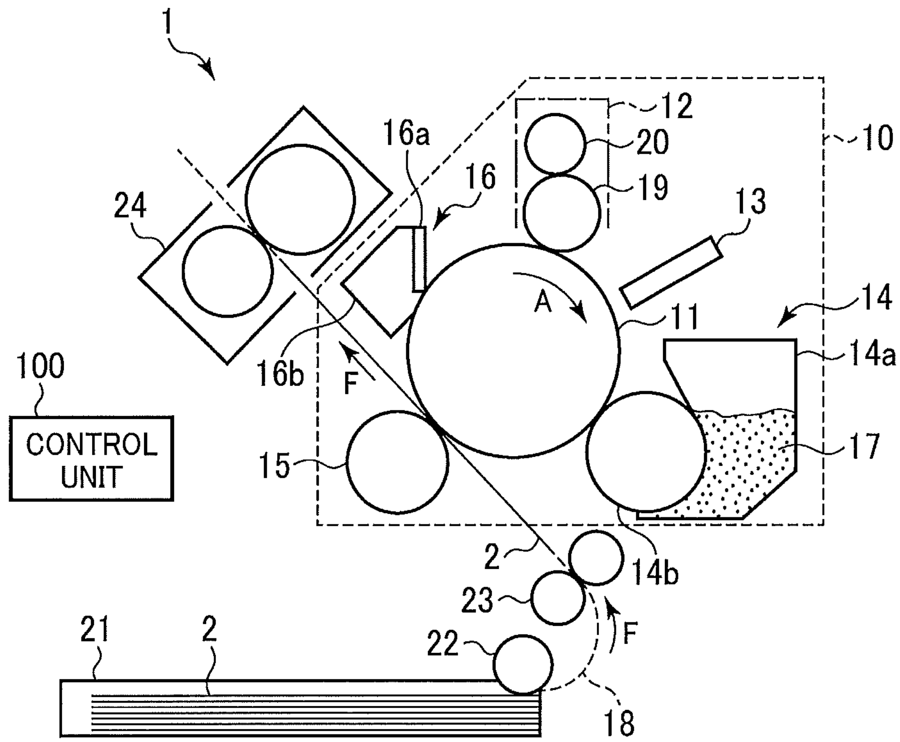
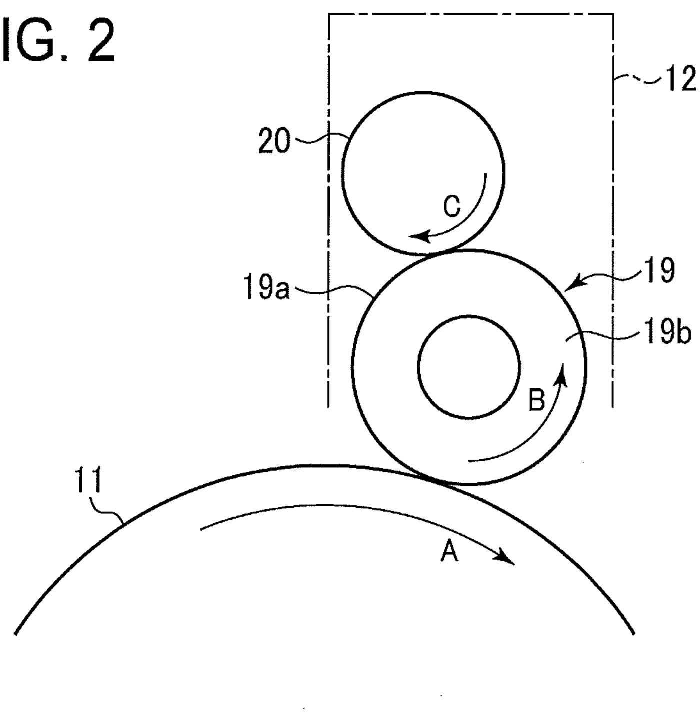


FIG. 1



1
12
20
19
10
16a
16
13
24
A
11
14
14a
100
16b
F
CONTROL
UNIT
15
17
2
14b
23
F
21
2
22
18

FIG. 2



12
20
C
19a
19
19b
B
11
A

FIG. 3

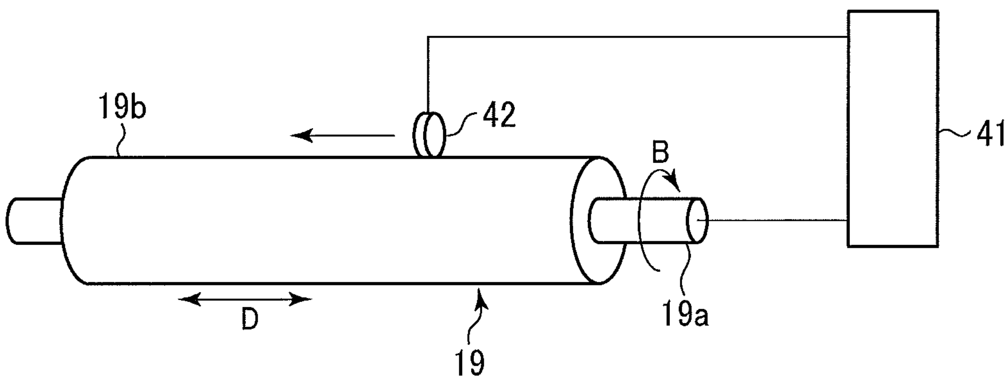


FIG. 4

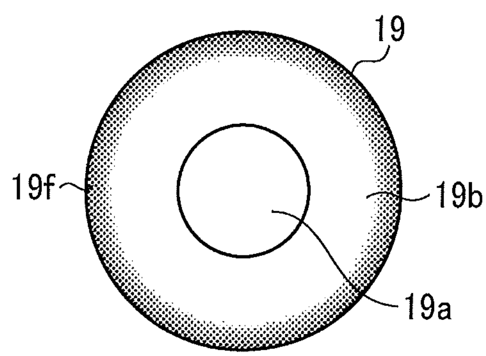


FIG. 5

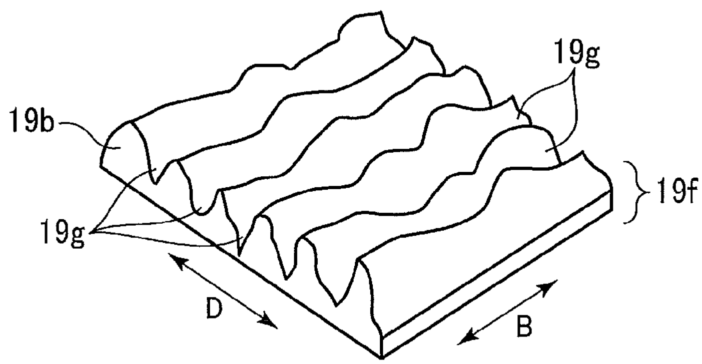


FIG. 6

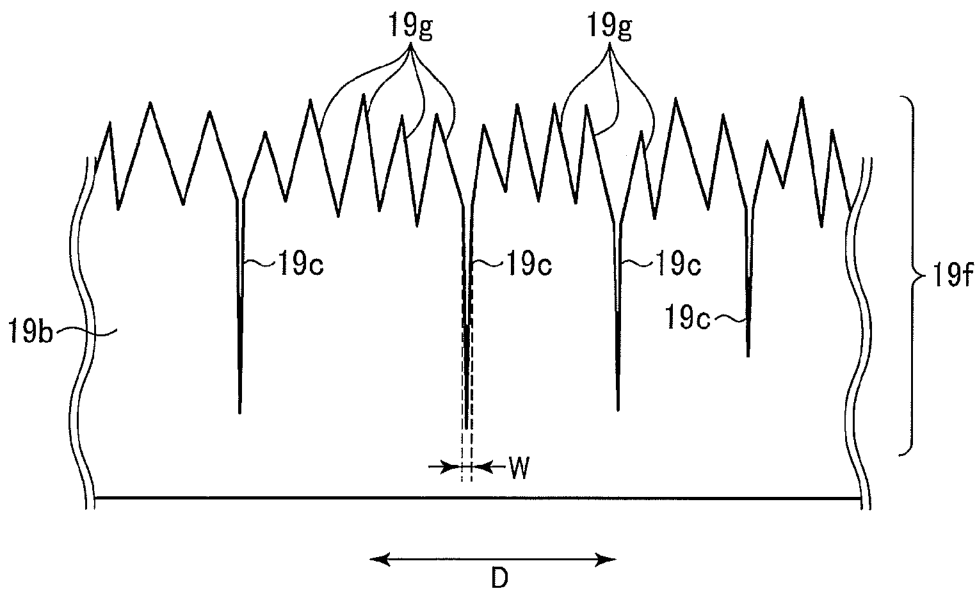


FIG. 7

		SAMPLE										
		1	2	3	4	5	6	7	8	9	10	11
BASE POLYMER	EPICHLOROHYDRIN RUBBER (WEIGHT PARTS)	60	80	40	80	40	85	35	60	60	60	60
	DIENE-BASED RUBBER (WEIGHT PARTS)	40	20	60	20	60	15	65	40	40	40	40
SURFACE PROPERTY	SURFACE TREATMENT (UV/COATING)	UV	UV	UV	UV	UV	UV	UV	UV	UV	COATING	UV & COATING
	PRESENSE (YES)/ ABSENCE (NO) OF CRACKS	YES	YES	YES	YES	YES	YES	YES	YES (SMALL)	NO	NO	YES
	MINIMUM VALUE OF CRACK DEPTHS (μM)	80	40	100	20	160	30	120	150	0	0	60
EVALUATION RESULT	AT START OF PRINTING OPERATION	○	○	○	○	○	○	×	○	○	○	×
	AT END OF CONTINUOUS PRINTING OPERATION	○	○	○	○	○	×		×	×	×	

FIG. 8

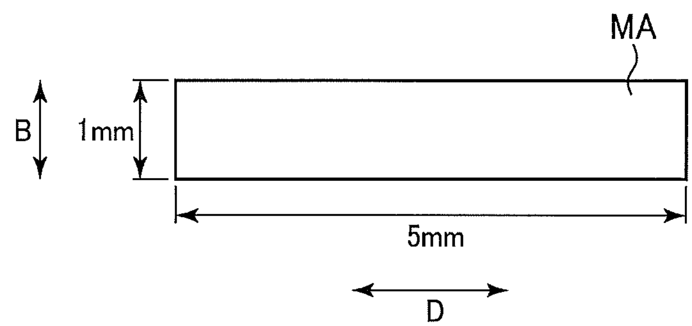


FIG. 9A

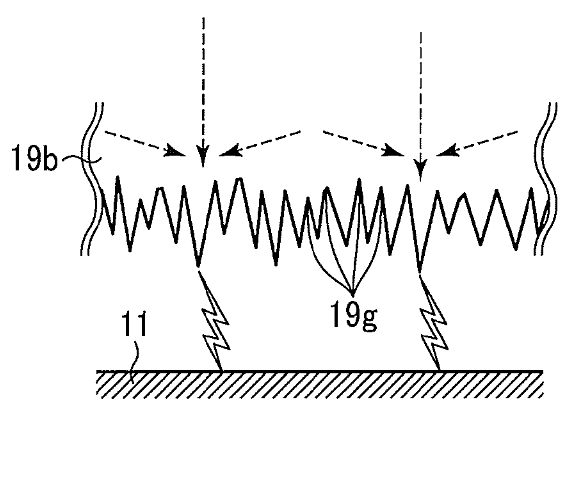
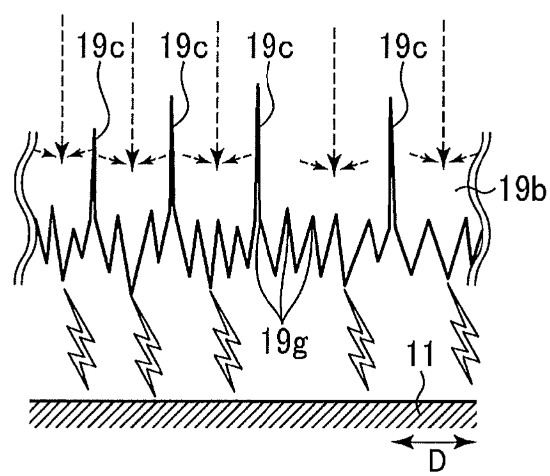


FIG. 9B



CHARGING DEVICE, IMAGE FORMING UNIT AND IMAGE FORMING APPARATUS

BACKGROUND OF THE INVENTION

The present invention relates to a charging device used in an electrophotographic process, and relates to an image forming unit and an image forming apparatus using the charging device.

In image forming apparatuses using an electrophotography process such as a printer, copier, facsimile or multifunction peripheral, a charging device is used to uniformly charge a surface of a photosensitive drum. There are several types of charging devices. A widely used charging device (i.e., a contact-charging type) includes a charging roller contacting the surface of the photosensitive drum and applied with a direct voltage.

The charging device of the contact-charging type has a disadvantage that a charging potential is likely to be uneven. To be more specific, the charging potential is likely to be uneven in an axial direction of the charging roller. Therefore, it has been proposed to form polishing grooves on a surface of the charging roller in a rotating direction of the charging roller to thereby reduce unevenness of the charging potential in the axial direction.

Further, as printing is repeatedly performed, the charging roller gradually becomes dirty. Therefore, it has been proposed to provide a cleaning roller that contacts and cleans the surface of the charging roller (see, for example, Japanese Laid-open Patent Publication No. 2010-54795).

However, in the conventional art, the surface of the charging roller may become worn by contact with the cleaning roller. In such a case, the charging potential on the surface of the photosensitive drum may become uneven, and printing quality may be degraded.

SUMMARY OF THE INVENTION

An aspect of the present invention is intended to prevent degradation of printing quality.

According to an aspect of the present invention, there is provided a charging device including a charging member that charges a surface of an image bearing body. The charging member includes a rotation shaft applied with a voltage, and a resilient conductive layer provided on an outer circumferential surface of the rotation shaft. The resilient conductive layer charges the surface of the image bearing body. The resilient conductive layer has a plurality of high resistance regions arranged at intervals in an axial direction of the rotation shaft.

With such a configuration, degradation of printing quality can be prevented.

BRIEF DESCRIPTION OF THE DRAWINGS

In the attached drawings:

FIG. **1** is a schematic sectional view of an image forming apparatus according to an embodiment of the present invention;

FIG. **2** is a schematic sectional view of a charging device according to the embodiment of the present invention;

FIG. **3** is an explanation view for explaining a measuring method of a resistance value of a charging roller according to the embodiment of the present invention;

FIG. **4** is a schematic sectional view showing the charging roller according to the embodiment of the present invention;

FIG. **5** is an explaining view for explaining a surface of a resilient conductive layer of the charging roller according to the embodiment of the present invention;

FIG. **6** is a schematic sectional view showing the surface of the resilient conductive layer of the charging roller according to the embodiment of the present invention;

FIG. **7** shows compositions and evaluation results of the charging rollers of Samples 1 through 11.

FIG. **8** is a schematic view showing a measurement area for measuring depths of cracks on the surface of the resilient conductive layer of the charging roller; and

FIGS. **9**A and **9**B are explanation views for illustrating a discharging from the surface of the resilient conductive layer of the charging roller according to the embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Hereinafter, the embodiment of the present invention will be described with reference to the attached drawings.

<Image Forming Apparatus>

FIG. **1** is a schematic sectional view of a printer **1** as an image forming apparatus according to the embodiment of the present invention. The printer **1** includes a control unit **100**, a feeding tray **21**, a feeding roller **22**, a pair of conveying rollers **23**, an image forming unit **10** and a fixing device **24**. The control unit **100** receives print command and image information from a host device via an interface unit (not shown), converts the received image information into image data signal, and performs image forming operation (i.e., printing operation). The feeding tray **21** stores a stack of media (i.e., recording sheets) **2** therein. The feeding roller **22** feeds the media **2** one by one out of the feeding tray **21**. The conveying rollers **23** convey the medium **2** to the image forming unit **10**. The image forming unit **10** forms a latent image based on the image data signal, develops the latent image using a toner (i.e., a developer) to form a toner image (i.e., a developer image), and transfers the toner image to the medium **2**. The fixing device **24** fixes the toner image to the medium **2**.

Hereinafter, the printer **1** will be described as including only one image forming unit **10** to form a single color image for convenience of explanation. However, it is also possible that the printer **1** includes a plurality of image forming units **10** to form a color image.

The image forming unit **10** is configured to form a toner image and transfer the toner image to the medium **2**. The image forming unit **10** includes a charging device **12**, an exposure device **13**, a developing device **14**, a transfer device **15** and a cleaning device **16**.

The photosensitive drum **11** as an image bearing body has a surface to be charged by the charging device **12**. The surface of the photosensitive drum **11** is exposed with light emitted by the exposure device **13**, and a latent image is formed on the surface of the photosensitive drum **11**.

The photosensitive drum **11** includes a conductive supporting body made of aluminum, stainless steel and the like, a charge generation layer formed on the conductive supporting body, and a charge transport layer formed on the charge generation layer.

The charge generation layer is a dispersion layer in which fine particles of charge generation substance are bound using binder resin. As the charge generation substance of the charge generation layer, it is possible to use various organic pigments, dyes and the like. For example, it is possible to use phthalocyanine compounds such as metal phthalocyanine in which metal, metal oxide or metal chloride thereof (such as copper indium chloride, gallium chloride, tin, oxytitanium, zinc and vanadium) is coordinated and non-metal phthalocyanine, or azo pigment such as monoazo, bisazo, trisazo and poly azo compounds.

As the binder resin of the charge generation layer, it is possible to use, for example, polyester resin, polyvinyl acetate, polyacrylic ester, polymethacrylic acid ester, polyester, polycarbonate, polyvinyl acetoacetal, polyvinyl propional, polyvinyl butyral, phenoxy resin, epoxy resin, urethane resin, cellulose ester, cellulose ether and the like.

The charge transport layer is mainly formed of charge transport substance and binder resin. As the charge transport substance of the charge transport layer, it is possible to use, for example, electron donors such as heterocyclic compounds (such as carbazole, indole, imidazole, oxazole, pyrazole, oxadiazole, pyrazoline or thiadiazole), aniline derivatives, hydrazone compounds, aromatic amine derivatives, stilbene derivatives, or polymers having a main chain or side chains comprising one of the above-mentioned compounds.

As the binder resin of the charge transport layer, it is possible to use, for example, vinyl polymer (such as polycarbonate, polymethylmethacrylate, polystyrene and polyvinyl chloride), polyester, polyester carbonate, polysulphone, polyimide, phenoxy, epoxy, silicon resin, copolymer of these materials, a partial cross-linking hardened material or the like, alone or in combination. In particular, polycarbonate is suitable. In addition, as needed, various additives such as antioxidant, sensitizer and the like may be added.

The conductive supporting body of the photosensitive drum **11** is formed of an aluminum tube. A surface of the aluminum tube is subjected to alumite treatment. The charge generation layer and the charge transport layer are laminated on the conductive supporting body. An outer diameter of the photosensitive drum **11** is 30.0 mm. The charge generation layer contains phthalocyanine as the charge generation substance, and polyvinyl acetoacetal-based resin as the binder resin. The charge transport layer contains hydrazine-based compound as the charge transport substance, and polycarbonate-based resin (added with antioxidant) as the binder resin. A thickness of the charge transport layer is 15 μm.

The charging device **12** includes a charging roller **19** and a cleaning roller **20**.

The charging roller **19** as a charging member is provided so as to contact the photosensitive drum **11**, and charges a surface of the photosensitive drum **11**. In this regard, the charging roller **19** may be provided in the vicinity of the photosensitive drum **11** in a non-contact manner. The charging roller **19** and the cleaning roller **20** will be described later.

The exposure device **13** (i.e., an exposure unit) is disposed downstream of the charging roller **19** in a rotating direction of the photosensitive drum **11** indicated by an arrow A. The exposure device **13** includes a light source such as an LED (Light Emitting Diode) head. The exposure device **13** emits light to the surface of the photosensitive drum **11** in accordance with the image data signal (to cause a charging potential of an exposed part of the photosensitive drum **11** to decrease) to thereby form a latent image on the surface of the photosensitive drum **11**.

The developing device **14** (i.e., a developing unit) is disposed downstream of the exposure device **13** in the rotating direction of the photosensitive drum **11** indicated by the arrow A. The developing device **14** develops the latent image on the surface of the photosensitive drum **11** to form a toner image. The developing device **14** includes a toner storage portion **14***a* for storing a toner **17** therein, and a developing roller **14***b* as a developer bearing body.

The toner storage portion **14***a* (i.e., a developer storage portion) stores the toner **17**, and supplies the toner **17** to the surface of the developing roller **14***b* so that a toner layer is formed on the developing roller **14***b*.

The developing roller **14***b* (i.e., a developer bearing body) includes a conductive supporting body and a conductive layer provided on an outer circumferential surface of the conductive supporting body. As needed, a surface of the conductive supporting body may be subjected to surface treatment or coating.

The conductive supporting body is connected to a developing bias power source (not shown), and is applied with, for example, a direct voltage of −250V (i.e., a developing voltage) for developing the latent image.

The conductive supporting body of the developing roller **14***b* is formed of a metal shaft of free-cutting steel (SUM). The conductive layer of the developing roller **14***b* is formed of urethane rubber (as a main component) added with carbon black (Ketjen black) as electron conductive agent. A resistance of the conductive layer is controlled by adjusting adding amount of carbon black. Further, a surface-treatment liquid containing isocyanate compound and carbon black (acethylene black) is coated on the surface of the conductive layer.

The toner **17** as a developer includes toner particles mixed with external additives. The toner **17** used in this embodiment is a non-magnetic single component negatively-chargeable polymerization toner. To be more specific, the toner **17** is obtained by forming the toner particles by mixing styrene-acrylonitrile copolymer, coloring agent and wax by emulsion polymerization method and by adding fine particles of silica and titanium oxide (i.e., external additives) to the toner particles.

A degree of circularity of the toner particles is in a range from 0.94 through 0.98. A mean particle diameter of the toner particles is in a range from 5.5 to 7.0 μm. A mean particle diameter of the external additives is in a range from 50 to 200 nm.

The transfer device **15** includes a transfer roller as a transfer member provided so as to contact the photosensitive drum **11**, and transfers the toner image from the surface of the photosensitive drum **11** to the medium **2**. The transfer roller includes a conductive supporting body and a conductive layer formed on an outer circumferential surface of the conductive supporting body. The conductive supporting body is formed of a shaft of free-cutting steel (SUM). The conductive layer is formed of rubber foam body. The rubber foam body is obtained by mixing epichlorohydrin rubber and acrylonitrile-butadiene rubber. A resistance value of the rubber foam body is controlled by adjusting a compounding ratio of epichlorohydrin rubber in the rubber foam body.

The rubber foam body has foam cells whose mean cell diameter is in a range from 50 to 300 μm. An asker-C hardness of the rubber foam body is approximately 35 degrees.

The cleaning device **16** as a developer cleaning unit is provided downstream of the transfer device **15** in the rotating direction of the photosensitive drum **11** indicated by the arrow A. The cleaning device **16** scrapes off and removes a residual toner **17** (i.e., the toner **17** remaining on the surface of the photosensitive drum **11** after transferring of the toner image) and contamination adhering to the surface of the photosensitive drum **11**.

The cleaning device **16** includes a cleaning blade **16***a* and a waste toner storage portion **16***b*.

The cleaning blade **16***a* includes a supporting body and a resilient blade member. An end of the blade member is fixed to the supporting body, and the other end of the blade member contacts the surface of the photosensitive drum **11** so as to scrape off the residual toner **17** and the contamination from the surface of the photosensitive drum **11**. The supporting body of the cleaning blade **16***a* is formed of electrolytic zinc-coated steel sheet (SECC). The blade member of the cleaning blade **16***a* is formed of polyurethane.

The waste toner storage portion **16***b* stores the residual toner **17** (i.e., a waste toner) scraped off from the surface of the photosensitive drum **11** by the cleaning blade **16***a*.

The cleaning device **16** is able to recover substantially all of the residual toner **17** adhering to the surface of the photosensitive drum **11**. In this regard, some of the external additives adhering to the surface of the photosensitive drum **11** are recovered by the cleaning device **16**, but some of the external additives may pass through the cleaning device **16** (i.e., are not recovered by the cleaning device **16**). Among the external additives having passed through the cleaning device **16**, the positively charged external additives and the external additives having large adhesion force may adhere to the charging roller **19**.

The feeding tray **21** is disposed below the image forming unit **10**, and stores the medium **2**.

The feeding roller **22** separates the media **2** stored in the feeding tray **21** one by one, and feeds each medium **2** into a medium conveying path **18** indicated by a broken line.

The conveying rollers **23** are disposed downstream of the feeding roller **22** along the medium conveying path **18**. The conveying rollers **23** convey the medium **2** (having been fed by the feeding roller **22**) to the image forming unit **10**.

The fixing device **24** is disposed downstream of the image forming unit **10** in a conveying direction of the medium **2** indicated by an arrow F along the medium conveying path **18**. The fixing device **24** applies heat and pressure to the medium **2** so as to fix the toner image to the medium **2**.

The control unit **100** includes a control part such as a CPU (Central Processing Unit) and a storage part such as a memory, and controls entire operation of the printer **1** based on control program (software) stored in the storage unit.

<Charging Device>

Next, the charging device **12** will be described with reference to FIG. **2**. FIG. **2** is a schematic sectional view showing the charging device **12** according to the embodiment of the present invention.

As shown in FIG. **2**, the charging roller **19** includes a conductive supporting body **19***a* and a resilient conductive layer **19***b* formed on an outer circumferential surface of the conductive supporting body **19***a*.

The conductive supporting body **19***a* (i.e., a rotation shaft) is connected to a charging bias power source (not shown), and is applied with a direct voltage (i.e., a charging voltage).

The resilient conductive layer **19***b* contains base polymer which is a mixture of epichlorohydrin rubber and diene-based rubber. The base polymer is added with, for example, thiourea cross-linking agent and promoter for causing cross-linking of epichlorohydrin rubber, and at least a kind of cross-linking agent (composed of sulfur and sulfur-containing cross-linking agent) and sulfur-containing promoter for causing cross-linking of diene-based rubber.

Further, at least a kind of additives such as cross-linking assistant, conductive agent, acid acceptor, antioxidizing agent, antistaling agent, processing aid, filler, pigment, neutralizer and bubble prevention agent may be added to the base polymer.

As epichlorohydrin rubber, it is possible to use, for example, epichlorohydrin homopolymer (CO), epichlorohydrin-ethylene oxide copolymer (ECO), epichlorohydrin/allyl glycidyl ether copolymer (GCO), epichlorohydrin/ethylene oxide/allyl glycidyl ether (GECO), copolymer of epichlorohydrin, propylene oxide and allyl glycidyl ether, copolymer of epichlorohydrin, ethylene oxide, propylene oxide and allyl glycidyl ether, alone or in combination. In this embodiment, epichlorohydrin rubber of the resilient conductive layer **19***b* is ECO.

As diene-based rubber, it is possible to use, for example, acrylonitrile-butadiene rubber (NBR), chloroprene rubber (CR), butadiene rubber (BR), styrene-butadiene rubber (SBR), isoprene rubber (IR) or natural rubber, alone or in combination. In this embodiment, NBR is a main component of diene-based rubber of the resilient conductive layer **19***b*.

<Characteristics of Charging Roller>

Next, electrical characteristics the charging roller **19** will be described. A resistance value of the resilient conductive layer **19***b* of the charging roller **19** relates to unevenness in charging potential and charging failure. Generally, if the resistance value of the resilient conductive layer **19***b* is too high, a variation in the resistance value of the resilient conductive layer **19***b* is likely to influence a distribution of electric charge on the surface of the resilient conductive layer **19***b*. In such a case, the charging potential on the surface of the photosensitive drum **11** may become uneven, and image defect is likely to occur. In contrast, if the resistance value of the resilient conductive layer **19***b* is too low, leakage of electric charge is likely to occur at scratches on the surface of the photosensitive drum **11**, which may cause charging failure and result in image defect.

For these reasons, there is an appropriate range of the resistance value of the resilient conductive layer **19***b*. For example, the appropriate range of the resistance value of the resilient conductive layer **19***b* is from 10^6 to $10^9\Omega$. In order to obtain the appropriate range of the resistance value, the resilient conductive layer **19***b* is formed using ion conductive material, ion conductive agent, carbon black, metal oxide or the like. The resilient conductive layer **19***b* may be formed using either electron conductive material or ion conductive material.

In this regard, variation in resistance value of the resilient conductive layer **19***b* is likely to influence the unevenness of the charging potential of the photosensitive drum **11**. Further, ion conductive material is more excellent than electron conductive material in effect of stabilizing the resistance value. Therefore, in this embodiment, the resilient conductive layer **19***b* is formed using ion conductive material for reducing the unevenness of the resistance value.

Therefore, in order to obtain the ion conductivity, conductive agent, carbon black, metal oxide and the like are added to epichlorohydrin rubber containing ethylene oxide so that the resistance value of the resilient conductive layer **19***b* is adjustable.

Further, NBR as polar rubber is used as the diene-based rubber so that the resistance value of the resilient conductive layer **19***b* is adjustable.

Next, the measurement of the resistance value of the charging roller **19** will be described. FIG. **3** is an explanation view for explaining a measuring method of the resistance value of the charging roller **19** according to the embodiment of the present invention.

In FIG. **3**, the resistance value of the charging roller **19** is measured using a resistance measuring instrument **41** (i.e., "High Resistance Meter 4339B" manufactured by Agilent Technologies Incorporated) and a bearing **42**. The bearing **42** is formed of stainless steel (SUS), and has a width of 2.0 mm and an outer diameter of 6.0 mm.

A terminal of the resistance measuring instrument **41** is brought into contact with the conductive supporting body **19***a*, and the other terminal of the resistance measuring instrument **41** is connected to the bearing **42**. The bearing **42** is biased against the surface of the resilient conductive layer **19***b* with a force of 10 gf. In this state, the charging roller **19** is rotated as shown by an arrow B in this state, and the resistance value of the charging roller **19** is measured during the rotation of the charging roller **19**.

Generally, the resistance value of the charging roller **19** changes depending on a temperature, humidity and applied voltage. In this embodiment, the resistance value of the charging roller **19** is measured at a temperature of 20° C. and humidity of 50% RH. A direct voltage of −500V is applied to the conductive supporting body **19***a* side.

Next, structural characteristics of the charging roller **19** will be described with reference to FIG. **2**.

In order to cause discharge from the resilient conductive layer **19***b* for charging the surface of the photosensitive drum **11** contacting the surface of the resilient conductive layer **19***b*, it is necessary to form a minute gap between the surface of the resilient conductive layer **19***b* and the surface of the photosensitive drum **11** to ensure a region contributing to discharge according to Paschen's law. Therefore, in order to obtain an appropriate nip (i.e., a contacting state) between the surface of the resilient conductive layer **19***b* and the surface of the photosensitive drum **11**, it is preferred that the Asker-C hardness of the resilient conductive layer **19***b* is lower than or equal to 85 degrees, and it is more preferred that the Asker-C hardness of the resilient conductive layer **19***b* is lower than or equal to 80 degrees.

FIG. **4** is a schematic cross sectional view of the charging roller **19** according to the embodiment of the present invention.

An oxide film **19***f* (i.e., a protection film) is formed on the surface of the resilient conductive layer **19***b*. The oxide film **19***f* is formed by irradiating the surface of the resilient conductive layer **19***b* with UV (Ultra-Violet) rays while rotating the charging roller **19**. That is, UV irradiation on the surface of the resilient conductive layer **19***b* causes oxidization of double-bonds of diene-based rubber contained in the resilient conductive layer **19***b*.

The oxide film **19***f* is formed by the UV irradiation, and therefore there is no distinct border between the oxide film **19***f* and other portions of the resilient conductive layer **19***b*. The oxide film **19***f* is thicker than at least a depth of cracks **16***c* (FIG. **6**) described later.

The formation of the oxide film **19***f* on the surface of the resilient conductive layer **19***b* provides following advantages. Firstly, the oxide film **19***f* prevents bloom or bleed, i.e., a phenomenon that low-molecular-weight component is precipitated from the resilient conductive layer **19***b*. That is, the surface of the photosensitive drum **11** can be prevented from being contaminated with precipitate.

Secondly, the oxide film **19***f* contributes to reducing the amounts of the residual toner **17** and the external additives remaining on the surface of the photosensitive drum **11** and adhering to the resilient conductive layer **19***b* from the photosensitive drum **11**. Further, even if the toner **17** and the external additives adhere to the resilient conductive layer **19***b*, the oxide film **19***f* makes it easy to remove the toner **17** and the external additives from the resilient conductive layer **19***b* by the cleaning roller **20**. Therefore, filming otherwise caused by the toner **17** and the external additives adhering to the surface of the resilient conductive layer **19***b* can be prevented.

Thirdly, the oxide film **19***f* contributes to reducing a friction coefficient between the resilient conductive layer **19***b* and the cleaning roller **20**, and therefore wear by contact between the resilient conductive layer **19***b* and the cleaning roller **20** can be reduced.

FIG. **5** is a schematic view showing the surface of the resilient conductive layer **19***b* of the charging roller **19** according to the embodiment of the present invention.

As shown in FIG. **5**, a plurality of grooves **19***g* (more specifically, polishing grooves) are formed on the surface of the resilient conductive layer **19***b* of the charging roller **19**. The polishing grooves **19***g* extend in a rotating direction of the charging roller **19** indicated by the arrow B (FIGS. **2**, **3** and **5**), and are arranged at intervals in an axial direction of the charging roller **19** as shown by an arrow D. The polishing grooves **19***g* are formed by tape polishing. With such polishing grooves **19***g*, the resilient conductive layer **19***b* has a predetermined surface roughness.

A maximum height roughness Ry (JIS B0601: 1994) of the resilient conductive layer **19***b* is preferably in a range from 1 to 40 μm, and more preferably in a range from 3 to 30 μm according to Paschen's law. This range varies depending on the applied voltage, use environment or the like.

In this embodiment, the surface roughness (i.e., the maximum height roughness Ry) of the resilient conductive layer **19***b* is measured using a surface roughness measuring instrument "Surf coder SE 3500" (manufactured by Kosaka Laboratory Limited) and a detector "PU-DJ2S" (manufactured by Kosaka Laboratory Limited).

FIG. **6** is an explanation view for explaining the surface of the resilient conductive layer **19***b* of the charging roller **19** according to the embodiment of the present invention.

When the surface of the resilient conductive layer **19***b* is subjected to the UV irradiation for a long time, small cracks **19***c* (i.e., high resistance regions) are formed on the surface of the resilient conductive layer **19***b*. To be more specific, the cracks **19***c* are formed at valleys of the polishing grooves **19***g*. The cracks **19***c* extend in the rotating direction of the charging roller **19** indicated by the arrow B, and are arranged at intervals in the axial direction of the charging roller **19** as indicated by the arrow D. In this embodiment, the cracks **19***c* are utilized to achieve a desired effect. In Comparison Example (Sample 10) described later, a coating film is formed on the resilient conductive layer **19***b* by dipping the charging roller **19** in surface treatment liquid and drying the charging roller **19**, instead of the UV irradiation.

In this regard, a surface resistance of the resilient conductive layer **19***b* is increased by the provision of the oxide film **19***f*.

<Cleaning Roller>

Referring back to FIG. **2**, the cleaning roller **20** is provided in contact with or in the vicinity of the surface of the resilient conductive layer **19***b*. It is possible that the cleaning roller **20** rotates following a rotation of the charging roller **19**. It is also possible that the cleaning roller **20** is driven to rotate at a different speed from the charging roller **19** so that the surface of the cleaning roller **20** slides on the surface of the charging roller **19**.

In the case where the cleaning roller **20** slides on the surface of the resilient conductive layer **19***b*, if a difference in circumferential speed (i.e., a circumferential speed difference) between the cleaning roller **20** and the charging roller **19** is too small, a cleaning performance may decrease. In contrast, if the circumferential speed difference is too large, the surface of the resilient conductive layer **19***b* may be worn, and adhering substances are pressed against the surface of the resilient conductive layer **19***b* to cause filming. Therefore, it is necessary to adjust the circumferential speed difference based on the amounts of the toner **17** and the external additives remaining on the photosensitive drum **11** and adhering to the resilient conductive layer **19***b* from the photosensitive drum **11**.

In this regard, a ratio of the circumferential speed of the cleaning roller **20** to the circumferential speed of the charging roller **19** is preferably in a range from 0.8 to 1.25.

In this embodiment, the cleaning roller **20** is provided in contact with the charging roller **19**. The ratio of the circumferential speed of the cleaning roller **20** to the circumferential speed of the charging roller **19** is set to 0.9.

Further, in this embodiment, the cleaning roller **20** includes a shaft body having an outer diameter of 6 mm, and a urethane foam having a thickness of 1.5 mm formed on an outer circumferential surface of the shaft body. An outer diameter of the cleaning roller **20** is 9 mm.

<Experiments>

In order to suppress degradation of printing quality, the charging rollers **19** of eleven samples were produced while varying material and surface treatment method of the resilient conductive layer **19***b*. The charging rollers **19** of these samples will be described with reference to FIGS. **3** through **6**.

FIG. **7** shows components and evaluation results of the charging rollers **19** of eleven samples, i.e., Samples 1 through 11. To be more specific, FIG. **7** shows weight parts of epichlorohydrin rubber and diene-based rubber (which constitute the base polymer) contained in the resilient conductive layer **19***b*, kinds of surface treatment (i.e., UV irradiation or coating), presence/absence of the cracks **19***c*, and a depth of the cracks **19***c*. FIG. **7** further shows evaluation results at a start of printing operation and at an end of continuous printing operation. Evaluation methods will be described later.

First, a common structure of the charging rollers **19** of Samples 1 through 11 will be described. The conductive supporting body **19***a* of the charging roller **19** was made of a metal shaft body formed of free-cutting steel (SUM), and had an outer diameter of 6 mm.

The resilient conductive layer **19***b* contained 60 weight parts of epichlorohydrin rubber (composed of epichlorohydrin-ethylene oxide copolymer (ECO)) and 40 weight parts of diene-based rubber (mainly composed of NBR). Further, necessary additives (such as cross-linking agent, cross-linking assistant and acid acceptor) of appropriate amounts were added to epichlorohydrin rubber and diene-based rubber.

The resulting material was then kneaded, was extruded by an extrusion molder into a tubular shape having an outer diameter of 13 mm and inner diameter of 5.5 mm, and was steam vulcanized at 150° C. for 3 hours. The resulting body (i.e., a tubular body) was fit to the conductive supporting body **19***a*, and was sintered in an oven for 150° C. for 1 hour. Then, the resulting body (i.e., a sintered body having a roller shape) was cooled to a room temperature.

Then, an outer circumferential surface of the resulting body was polished using a grinding stone. Then, polishing chips were removed, and the outer circumferential surface of the polished body was cleaned. Then, the resulting body (i.e., a polished body) was further polished by wet tape polishing (i.e., final polishing) so as to obtain the resilient conductive layer **19***b* (fitted to the conductive supporting body **19***a*) having an outer diameter of 12 mm. As a result, the charging roller **19** was obtained.

Next, the charging rollers **19** of Samples 1 through 11 will be described.

<Sample 1>

The charging roller **19** of Sample 1 was obtained by forming the oxide film **19***f* on the surface of the resilient conductive layer **19***b* by the UV irradiation so that small cracks **19***c* (i.e., high resistance regions) were formed at valleys of the polishing grooves **19***g* as shown in FIG. **6**. That is, a plurality of cracks **19***c* extending in the rotating direction of the charging roller **19** were formed on the surface of the resilient conductive layer **19***b* by the UV irradiation of the resilient conductive layer **19***b*.

The UV irradiation was performed using a metal halide lamp (i.e., a UV light source). An output of the UV light source was set to 120 W/cm, and a distance (i.e., a UV irradiation distance) from the UV light source to the resilient conductive layer **19***b* was set to 50 mm. A time for UV irradiation (i.e., a UV irradiation time) was set to 20 minutes.

The depths of cracks **19***c* were determined as follows. FIG. **8** is a schematic view showing a measurement area MA for measuring the depths of the cracks **19***c*. The depths of the cracks **19***c* in the measurement area MA of 5 mm^2 on the surface of the resilient conductive layer **19***b* were measured by the above described surface roughness measuring instrument. The measurement area MA had a length of 1 mm in the rotating direction of the charging roller **19** indicated by the arrow B, and a length of 5 mm in the axial direction of the charging roller **19** indicated by the arrow D. Then, among the measured cracks **19***c* in the measurement area MA, five cracks **19***c* from the deepest one were selected. Among the selected five cracks **19***c*, a depth of the shallowest crack **19***c* was defined as a minimum depth per unit area (1 mm^2). The minimum depth of the crack **19***c* per unit area (1 mm^2) is also referred to as a "minimum value of crack depths".

Regarding the charging roller **19** of Sample 1, the minimum value of the crack depths was 80 μm.

Further, a width between the cracks **19***c* in the axial direction D (indicated by an arrow W in FIG. **6**) was less than or equal to 80 μm at its widest part. Each crack **19***c* had a length in the rotating direction (indicated by the arrow B) in a range from several tens μm to several hundreds μm.

<Sample 2>

The charging roller **19** of Sample 2 was different from the charging roller **19** of Sample 1 in composition ratio of epichlorohydrin rubber and diene-based rubber contained in the resilient conductive layer **19***b*. The resilient conductive layer **19***b* of the charging roller **19** of Sample 2 contained 80 weight parts of epichlorohydrin rubber and 20 weight parts of diene-based rubber. The minimum value of the crack depths was 40 μm.

<Sample 3>

The charging roller **19** of Sample 3 was different from the charging roller **19** of Sample 1 in composition ratio of epichlorohydrin rubber and diene-based rubber contained in the resilient conductive layer **19***b*. The resilient conductive layer **19***b* of the charging roller **19** of Sample 3 contained 40 weight parts of epichlorohydrin rubber and 60 weight parts of diene-based rubber. The minimum value of the crack depths was 100 μm.

<Sample 4>

The charging roller **19** of Sample 4 was different from the charging roller **19** of Sample 2 in that the UV irradiation distance was set to 100 mm and the UV irradiation time was set to 15 minutes. The minimum value of the crack depths was 20 μm.

<Sample 5>

The charging roller **19** of Sample 5 was different from the charging roller **19** of Sample 3 in that the UV irradiation distance was set to 20 mm and the UV irradiation time was set to 30 minutes. The minimum value of the crack depths was 160 μm.

<Sample 6>

The charging roller **19** of Sample 6 was different from the charging roller **19** of Sample 1 in composition ratio of epichlorohydrin rubber and diene-based rubber contained in the resilient conductive layer **19***b*. The resilient conductive layer **19***b* of the charging roller **19** of Sample 6 contained 85 weight parts of epichlorohydrin rubber and 15 weight parts of diene-based rubber. The minimum value of the crack depths was 30 μm.

<Sample 7>

The charging roller **19** of Sample 7 was different from the charging roller **19** of Sample 1 in composition ratio of epichlorohydrin rubber and diene-based rubber contained in the resilient conductive layer **19***b*. The resilient conductive layer **19***b* of the charging roller **19** of Sample 7 contained 35 weight parts of epichlorohydrin rubber and 65 weight parts of diene-based rubber. The minimum value of the crack depths was 120 μm.

<Sample 8>

The charging roller **19** of Sample 8 was different from the charging roller **19** of Sample 1 in that the UV irradiation time was set to 10 minutes so as to reduce the depths of the cracks **19***c*. The minimum value of the crack depths was 15 μm.

<Sample 9>

The charging roller **19** of Sample 9 was different from the charging roller **19** of Sample 1 in that the UV irradiation time was set to 5 minutes so as not to form cracks **19***c* on the surface of the resilient conductive layer **19***b*.

<Sample 10>

The charging roller **19** of Sample 10 was different from the charging roller **19** of Sample 1 in a surface treatment of the resilient conductive layer **19***b*. The resilient conductive layer **19***b* of the charging roller **19** of Sample 10 was not subjected to the UV irradiation after being polished by tape polishing and being cleaned. Instead, a coating film was formed on the resilient conductive layer **19***b* by impregnating the charging roller **19** in surface treatment liquid and then drying the charging roller **19**. The surface treatment liquid was mixture of 100 weight parts of ethyl acetate as organic solvent, and 20 weight parts of hexamethylene diisocyanate (HDI) as isocyanate compound.

The surface treatment was performed by impregnating the charging roller **19** in the surface treatment liquid for 30 seconds so that the isocyanate compound and the organic solvent adhered to and permeated into the surface of the resilient conductive layer **19***b*. Then, the charging roller **19** was taken out from the surface treatment liquid, and was dried in an oven at 120° C. for 1 hour so that the organic solvent was evaporated. The isocyanate compound remained on the surface of the resilient conductive layer **19***b*, and was hardened. In this way, a coating film was formed on the surface of the resilient conductive layer **19***b*.

The charging roller **19** of Sample 10 was not subjected to the UV irradiation, and therefore no crack was formed on the surface of the resilient conductive layer **19***b*.

<Sample 11>

The charging roller **19** of Sample 11 was different from the charging roller **19** of Sample 1 in surface treatment of the resilient conductive layer **19***b*. The resilient conductive layer **19***b* of the charging roller **19** of Sample 11 was subjected to the UV irradiation, and then a coating film was formed on the resilient conductive layer **19***b* by impregnating the charging roller **19** in the surface treatment liquid and drying the charging roller **19** as described with respect to Sample 10.

In this way, the cracks **19***c* were formed on the surface of the resilient conductive layer **19***b* of the charging roller **19** of Sample 11. The cracks **19***c* extended in the rotating direction of the charging roller **19**. Further, the coating film was formed on the surface of the resilient conductive layer **19***b* covering the cracks **19***c*. The minimum value of the crack depths was 60 μm.

<Printing Tests>

Printing tests were performed by mounting each of the charging rollers **19** of Samples 1 through 11 to the printer **1**. As the printer **1**, a color LED printer ("C711dn" manufactured by Oki Data Corporation) was used. Evaluation was performed at a start of printing operation and at an end of continuous printing operation.

The evaluation at the start of the printing operation was performed by printing an image on a sheet (i.e., a first sheet) after mounting the charging roller **19** to be tested to the printer **1**, and checking a quality of the printed image.

Further, continuous printing operation on 3000 sheets per day was performed for 10 days. That is, continuous printing operation was performed on 30,000 sheets in total. The evaluation at the end of the continuous printing operation was performed by printing an image on a sheet after the continuous printing operation on 30,000 sheets, and checking a quality of the printed image.

The printing tests were performed in three environments: a normal-temperature-and-normal-humidity environment where a temperature is 24±4° C. and a humidity is 50±15% RH, a high-temperature-and-high-humidity environment where the temperature is 28° C. and the humidity is 85% RH, a low-temperature-and-low-humidity environment where the temperature is 10° C. and the humidity is 15% RH.

Two print patterns (images) were used in the printing tests. More specifically, a 5% coverage image and a "1 by 1" halftone image of 600 dpi are used. In this regard, the term "coverage" indicates a percentage of an area of a printed portion per unit area. For example, a solid image is a 100% coverage image, and the "1 by 1" halftone image is a 25% coverage image.

<Evaluation Results>

Next, the evaluation results will be described. If a defect was found in any one of the images (i.e., the 5% coverage image and the 1 by 1 halftone image) printed in the three environments, the evaluation result was "X" (poor). If no defect was found in the images printed in the three environments, the evaluation result was "0" (good).

When the charging rollers **19** of Samples 1 through 5 were used, no defect was found in the images printed at the start of the printing operation and at the end of the continuous printing operation. A reason thereof will be described later with reference to FIG. **9**B.

When the charging roller **19** of Sample 6 was used, vertical strips and vertical belt-like patterns were found in the images printed at the end of the continuous printing operation. A reason thereof will be described below. In the resilient conductive layer **19***b* of sample 6, a compounding ratio of diene-based rubber (with respect to epichlorohydrin rubber) was relatively small. For this reason, a function of the oxide film **19***f* (as a protection film) formed on the surface of the resilient conductive layer **19***b* was not sufficiently obtained. Therefore, the surface of the resilient conductive layer **19***b* was scratched in the rotating direction by contact with the cleaning roller **20**, with the result that the vertical strips and vertical belt-like patterns appeared on the printed image.

When the charging roller **19** of Sample 7 was used, the density unevenness was found in the images printed at the start of the printing operation. A reason thereof will be described below. In the resilient conductive layer **19***b* of sample 6, a compounding ratio of epichlorohydrin rubber (with respect to diene-based rubber) was relatively small. For this reason, a resistance value of the resilient conductive layer **19***b* was not sufficiently lowered. Due to the ion conductivity of the resilient conductive layer **19***b*, the resistance value of the resilient conductive layer **19***b* increased particularly in the low-temperature-and-low-humidity environment. A charging function of the charging roller **19** (i.e., a function to uniformly charge the surface of the photosensitive drum **11**) was degraded by such a particularly high resistance value. Therefore, the charging roller **19** could not uniformly charge the surface of the photosensitive drum **11**, with the result that density unevenness of the printed image occurred.

Since the evaluation result at the start of the printing operation was poor (X), the evaluation was not performed after the continuous printing operation.

When the charging rollers **19** of Samples 8 and 9 were used, lateral strips were found in the images printed at the end of the continuous printing operation. A reason thereof will be described below. As tips of ridges between the polishing grooves **19***g* of the resilient conductive layer **19***b* were worn by contact with the cleaning roller **20**, the surface roughness of the resilient conductive layer **19***b* decreased. Therefore, portions where the resistance value was locally small appeared, with the result that the resistance value of the resilient conductive layer **19***b* became uneven.

FIGS. **9**A and **9**B are schematic views for illustrating discharge from the surface of the resilient conductive layer **19***b*. FIG. **9**A shows how discharge occurs from the surface of the resilient conductive layer **19***b* in the case where no crack is formed on the surface of the resilient conductive layer **19***b*. FIG. **9**B shows how discharge occurs from the surface of the resilient conductive layer **19***b* in the case where cracks **19***c* are formed on the surface of the resilient conductive layer **19***b*.

As shown in FIG. **9**A, in each of the charging roller **19** of Samples 18 and 19, no crack was formed on the surface of the resilient conductive layer **19***b*. When electrical charges were discharged from the surface of the resilient conductive layer **19***b* (so as to charge the surface of the photosensitive drum **11**), discharge was likely to occur at a portion where a distance between the surface of the resilient conductive layer **19***b* and the surface of the photosensitive drum **11** was short. The electrical charges moved along the surface of the resilient conductive layer **19***b* as shown by dashed arrows, and there occurred a portion where discharge did not occur or was very weak. Therefore, the unevenness of the charging potential occurred on the surface of the photosensitive drum **11**, with the result that the lateral stripes were formed on the printed image.

In contrast, as shown in FIG. **9**B, in each of the charging roller **19** of Samples 1 through 5, the cracks **19***c* were formed on the surface of the resilient conductive layer **19***b*. Even in these cases, tips of ridges between the polishing grooves **19***g* of the resilient conductive layer **19***b* may be worn by contact with the cleaning roller **20** (i.e., the surface roughness of the resilient conductive layer **19***b* may decrease), so that a portion where the resistance value was locally small may appear as in Samples 8 and 9. However, since the cracks **19***c* were formed on the surface of the resilient conductive layer **19***b*, the electric charges were less likely to move along the surface of the resilient conductive layer **19***b*. In other words, the cracks **19***c* functioned as high resistance regions suppressing movement of the electric charges in the axial direction of the charging roller **19** (indicated by the arrow D) along the surface of the resilient conductive layer **19***b*. Therefore, the unevenness of the charging potential did not occur, and the charging roller **19** uniformly charged the surface of the resilient conductive layer **19***b*.

When the images printed using the charging rollers **19** of Samples 8 and 9 were compared with each other, the image printed using the charging roller **19** of Sample 8 was better than the image printed using the charging roller **19** of Sample 8. Although the image printed using the charging roller **19** of Sample 8 was not at a satisfactory level, it is understood that degradation of the printing quality was restricted to some extent because the cracks **19***c* were formed on the surface of the resilient conductive layer **19***b* of Sample 8.

When the charging roller **19** of Sample 10 was used, lateral strips were found in the images printed after the continuous printing operation. A reason thereof will be described below. That is, the coating film formed on the surface of the resilient conductive layer **19***b* was harder than the oxide film **19***f* (of the charging rollers **19** of Samples 1 through 5) formed by the UV irradiation of the rubber. Therefore, an amount of wear of the surface of the resilient conductive layer **19***b* was small, and filming occurred at the surface of the resilient conductive layer **19***b* by contact with the cleaning roller **20**.

Therefore, there occurred a portion on the surface of the resilient conductive layer **19***b* where the resistance value is locally high. That is, the resistance value on the surface of the resilient conductive layer **19***b* became uneven, and lateral strips appeared in the printed images as in Samples 8 and 9.

When the charging roller **19** of Sample 11 was used, the density unevenness was found in the images printed in the low-temperature-and-low-humidity environment at the start of the printing operation. A reason thereof will be described below. That is, since the coating film was formed on the cracks **19***c* on the surface of the resilient conductive layer **19***b* by the UV irradiation, the total thickness of the resilient conductive layer **19***b* increased. As the thickness of the resilient conductive layer **19***b* increases, the resistance value at the surface of the resilient conductive layer **19***b* also increases. Further, due to the ion conductivity of the resilient conductive layer **19***b*, the resistance value of the resilient conductive layer **19***b* increases particularly in the low-temperature-and-low-humidity environment. The charging function of the charging roller **19** was degraded by the particularly high resistance value. For these reasons, the density unevenness of the printed image occurs.

Regarding Sample 11, since the evaluation result at the start of the printing operation is poor (X), the evaluation is not performed after the continuous printing operation.

CONCLUSION

As a result, it is understood that the surface of the photosensitive drum **11** can be uniformly charged by providing cracks **19***c* on the surface of the resilient conductive layer **19***b*. To be more specific, the surface of the photosensitive drum **11** can be uniformly charged by providing at least one crack **19***c* (whose depth from the surface of the resilient conductive layer **19***b* is greater than or equal to 20 μm) per unit area (1 mm^2) on the surface of the resilient conductive layer **19***b*. Therefore, the degradation of printing quality can be suppressed.

The minimum value of the crack depths is preferably in a range from 20 to 200 μm.

Further, the resilient conductive layer **19***b* contains epichlorohydrin rubber and diene-based rubber. The composition ratio of epichlorohydrin rubber to diene-based rubber is preferably in a range from 80/20 (i.e., 80 weight parts of epichlorohydrin rubber and 20 weight parts of diene-based rubber) to 40/60 (i.e., 40 weight parts of epichlorohydrin rubber and 60 weight parts of diene-based rubber). In other words, the amount of the diene-based rubber is preferably in a range from 25 weight parts to 150 weight parts, with respect to 100 weight parts of epichlorohydrin rubber. With such a composition, it becomes possible to prevent decrease in function of the protection film (i.e., the oxide film **19***f*) on the surface of the resilient conductive layer **19***b* due to the UV irradiation, and it becomes possible to prevent degradation of the printing quality.

Further, from the evaluation result of Sample 11, it is preferred that no layer (that causes an increase in resistance value and impairs the charging function) is formed on the surface of the resilient conductive layer **19***b* having the cracks **19***c*.

Advantage of Embodiment

As described above, according to the embodiment of the present invention, the charging potential on the surface of the photosensitive drum can be made even by providing the cracks **19***c* on the surface of the resilient conductive layer of the charging roller. Accordingly, degradation of the printing quality can be prevented.

In the above described embodiment, the cracks **19***c* have been described as an example of the high resistance regions. However, the high resistance regions are not limited to the cracks **19***b*. It is also possible to use other high resistance regions as long as the high resistance regions suppress the movement of the electric charges along the surface of the resilient conductive layer **19***b*.

In the above described embodiment, the printer has been described as an example of the image forming apparatus. However, the present invention is not limited to the printer, but is applicable to various types of image forming apparatuses using electrophotography such as a facsimile machine, a copier a multifunction peripheral or the like.

While the preferred embodiments of the present invention have been illustrated in detail, it should be apparent that modifications and improvements may be made to the invention without departing from the spirit and scope of the invention as described in the following claims.

What is claimed is:

1. A charging device comprising:

a charging member that charges a surface of an image bearing body;

wherein the charging member includes a rotation shaft applied with a voltage, and a resilient conductive layer provided on an outer circumferential surface of the rotation shaft, the resilient conductive layer having a plurality of grooves on a surface thereof;

wherein the resilient conductive layer further has a plurality of cracks formed at valleys of the grooves; and

wherein the cracks extend in a rotating direction of the charging member, and are arranged at intervals in an axial direction of the rotation shaft.

2. The charging device according to claim **1**, wherein:

the cracks have a depth greater than or equal to 20 μm from the surface of the resilient conductive layer; and

at least five cracks are provided in an area of 5 mm^2 on the surface of the resilient conductive layer parallel to the axial direction.

3. The charging device according to claim **1**, wherein:

the cracks have a depth greater than or equal to 20 μm from the surface of the resilient conductive layer; and

at least one crack is provided in an area of 1 mm^2 on the surface of the resilient conductive layer parallel to the axial direction.

4. The charging device according to claim **1**, wherein the cracks are formed by irradiating the surface of the resilient conductive layer with ultraviolet rays.

5. The charging device according to claim **1**, wherein the grooves extend in the rotational direction of the charging member.

6. The charging device according to claim **1**, wherein:

a protection film is formed on the surface of the resilient conductive layer; and

the cracks are formed in the protection film.

7. The charging device according to claim **6**, wherein the protection film is an oxide film.

8. The charging device according to claim **6**, wherein a protection film covers surfaces of the cracks.

9. The charging device according to claim **1**, wherein the voltage applied to the rotation shaft is a direct voltage.

10. The charging device according to claim **1**, wherein the resilient conductive layer contains 20 weight parts or more of diene-based rubber with respect to 100 weight parts epichlorohydrin rubber.

11. The charging device according to claim **1**, wherein the resilient conductive layer contains 150 weight parts or less of diene-based rubber with respect to 100 weight parts epichlorohydrin rubber.

12. An image forming unit comprising the charging device according to claim **1**.

13. An image forming apparatus comprising the charging device according to claim **1**.

14. The charging device according to claim **1**, wherein the cracks do not cross each other.

15. The charging device according to claim **1**, wherein the grooves have a maximum height roughness Ry of between 1 μm and 40 μm.

* * * * *